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Conference Report

WORKSHOP ON KNOWLEDGE-BASED SYSTEMS INTEROPERABILITY Gaithersburg, MD November 3-4, 1997

Report prepared by

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1. Introduction

On November 3 and 4, 1997, the National Institute of Standards and Technology sponsored[2] an information-gathering workshop that focused on Knowledge-Based Systems Interoperability. Held in Gaithersburg, MD on the NIST campus, and in response to the growing need for integrating knowledge in distributed computing environments, the workshop addressed the general issue of interoperability among knowledge-based systems[3] especially in engineering design and manufacture. The workshop, which hosted about 25 participants, included three major activities. These are: 1) seven presentations from developers, vendors and users, 2) group discussions on knowledge-based system interoperability-its present capabilities and some of its main drawbacks—and 3) a general session to target specific research and development, and end-user needs. This report documents the workshop background and goals, summarizes the workshop program, and provides a summary of the workshop results.

2. Workshop Background and Goals

The purpose of this workshop was to bring together KBS developers, vendors and users from different engineering disciplines to discuss matters of common interest concerning software interoperability. Functional interoperability is fundamental to the success of complex engineering processes such as collaborative design. Although much effort has been put forth in standardizing geometric product data exchange with the development of the international STandard for the Exchange of Product model data (STEP), ISO 10303 [2], such standards do not yet address the exchange of parametric data such as design rationale, functional specification and design intent. To achieve functional interoperability, computer-aided engineering[4] (CAE) applications in general, and KBS in particular, software needs to be implemented in such a way that the exchange of data and knowledge can occur without loss of information, tolerance or robustness. How to bring about this interoperation is precisely the reason for this workshop.

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[2] Specifically, this workshop was sponsored by the EDT Group, a part of the Manufacturing Systems Integration Division (MSID) in the Manufacturing Engineering Laboratory (MEL), under the auspices of the Defense Advanced Research Projects Agency's (DARPA's) Rapid Design Exploration and Optimization (RaDEO) program.

[3] A knowledge-based system, or KBS, also known as an expert system, is software that has some knowledge or expertise about a specific, narrow domain, and is implemented such that the knowledge base (KB) and the control architecture are separated. Knowledge-based systems have capabilities that often include inferential processing (as opposed to algorithmic processing), explaining rationale to users and generating non-unique results [1].

[4] In the context of this paper, CAE refers to generic computer-aided activities such as computer-aided design (CAD) computer-aided manufacture (CAM) and finite element analysis (FEA).

The workshop mission was to provide an open forum for KBS developers, users, vendors, and engineers and manufacturers, to discuss the state-of-the-art, identify gaps in current technology, and to begin proposing solutions to close those gaps. Specific workshop goals included the following:

- to provide an overview of the state-of-the-art in KBS interoperability in industry, government and academia,
- to present industry case studies on current interoperability practices,
- to identify interoperability standards and technology issues, and
- to identify actions that will aid in research and development in KBS interoperability, especially in collaborative engineering projects.

The workshop program and results, which correspond to the last two items above, are described below.

3. Program

The workshop was organized as a series of presentations from speakers representing KBS developers, KBS researchers, and engineers who use KB and CAE systems in their design and manufacturing activities (two developers, three researchers and two engineers). To begin the workshop, NIST personnel provided input on the state of comparable standards and government activity in generating those standards. The proceedings for the workshop [3], and the link to the workshop Uniform Resource Location (URL), *http://www.nist.gov/edt/resources/EDTconf.htm,* includes the workshop agenda, list of participants, presentation abstracts and presentation slides.

Following the morning of presentations on November 3, workshop organizers split the participants into two subgroups. Each subgroup brainstormed on one of these two themes:

I. State of the Art in KBS Interoperability.

II. Barriers and Requirements for KBS Interoperability.

The subgroups reconvened to discuss the issues raised and to report on each subgroup's findings to the entire workshop. The second day was used for a general discussion, refinement of our findings, and for the group to agree on a list of action items to be taken.

4. Workshop Results

Of the more than one dozen issues identified by the groups (and listed below), two main themes emerged:

1. Interoperability among KB and CAE systems is a major bottleneck today.
2. Current standards do not address many of the interoperability issues associated with KBS.

Within these main themes, five concepts emerged as priority issues. These are:

Characterization There is strong need to characterize—perhaps even standardize—the capabilities, behavior and underlying philosophy of KB systems.

Usability Engineers and manufacturers who use KB and CAE systems must not be unduly burdened with interoperability issues.

Vocabulary For design and manufacturing applications, a core set of primitives (such as artifact, design plan, goal, form, function and behavior) need to be understood and represented in a standardized way so that meaningful exchange of such knowledge can be achieved.

Collaboration The commercial, academic and governmental communities should as much as possible to address the interoperability issues in a more meaningful way than in the past.

Cost The cost of KB systems and their interoperability must be manageable for midsize companies.

Participants also identified 14 issues as being important in KBS interoperability. These are listed below:

1. Knowledge representation (KR) is the critical element for interoperability because if different KR schemes need to interact, there must be some commonality among representations. One possible solution is to link different KR schemes by using the Knowledge Interchange Format, KIF [4], with a formal, explicit specification of a conceptualization, often referred to as a frame ontology [5].
2. Mediation is important for interoperability because it places context on a specific knowledge base, otherwise known as semantic heterogeneity.
3. Problem solving cooperation is desirable because such understanding limits the amount of knowledge sharing in specific interoperable transactions.
4. Knowledge base validation is important for interoperability because of the consistency issue associated with individual KBs, and the ramifications for downstream propagation of possible misinformation.
5. Negotiation is an important attribute in interoperable KB systems because of the constrained nature of most engineering design and manufacturing activities.

6. Knowledge base comprehension is important for global context. To efficiently interoperate, KB systems require entities that describe what knowledge a specific KB contains, thereby streamlining search.
7. Knowledge capture is clearly achievable for specific domains, yet this activity remains a bottleneck.
8. Knowledge history, or meta-knowledge, is important to trace the reason for a particular conclusion or action.
9. Knowledge types must be varied for interoperability to be effective. Many types of objects should be recognizable—business objects, design objects, management objects and manufacturing objects.
10. KIF was developed as an interchange format and may prove very useful as a building block in representing knowledge across different KR schemes.
11. Design rationale is one level of knowledge that must be made interoperable.
12. Common Object Broker Request Architecture, or CORBA™ [6], compliance is important for communication across different platforms and applications implemented in different languages.
13. Java™ [7] compliance may be important for distributing knowledge across networks.
14. Problem solving method libraries are important so that meta-knowledge can be used to locate appropriate knowledge sources.

5. Action Items

The workshop concluded with a set of five action items that participants agreed to address. These are:

1. Begin surveying KBS developers and characterizing existing tools.
2. Develop sample practical problem involving multiple KB and CAE systems.
3. Define a taxonomy of domain entities, or primitives, that lend themselves specifically to interoperability in design and manufacture.
4. Explore the similarities and differences between KIF and the STEP data modeling language, EXPRESS, and its extensions.
5. Draft position paper on KBS interoperability discussing goals, challenges, strategies and areas of application.

NIST is taking the lead on the first four action items, while industry is leading the position paper effort.

6. References

[1] M. L. Maher, and R. H. Allen, Expert System Components, in Expert Systems for Civil Engineers: Technology and Application, M. L. Maher, ed., ASCE, New York (1987).
[2] Product data representation and exchange: Overview and fundamental principles, ISO 10303-1:1994.
[3] R. H. Allen, and R. D. Sriram, Proceedings of the 1997 Knowledge-based Systems Interoperability Workshop, NISTIR 6111, NIST, Gaithersburg, MD (1998).
[4] M. Genesereth, and R. Fikes, Knowledge Interchange Format, Version 3.0 Reference Manual, Computer Science Department, Stanford University, Tech Report Logic 92-1.
[5] J. G. McGuire, et al., SHADE: Technology for Knowledge-Based Collaborative Engineering, in Concurrent Eng. Res. Applic. **1** (3), (1993).
[6] The Common Object Request Broker: Architecture and Specification, Volume 1, Object Management Group, Framingham, MA, July 1996.
[7] M. Campione, and K. Walrath, The Java Tutorial: Object-Oriented Programming for the Internet (Java Series), Addison-Wesley (1996).